Model of effects of aircraft noise on communities

Sleep disturbance
Speech interference
Activity interference
Short-term annoyance
…

Non-acoustic factors

Short-term effects

Long-term effects

Acoustic factors

Complaints / Other public action
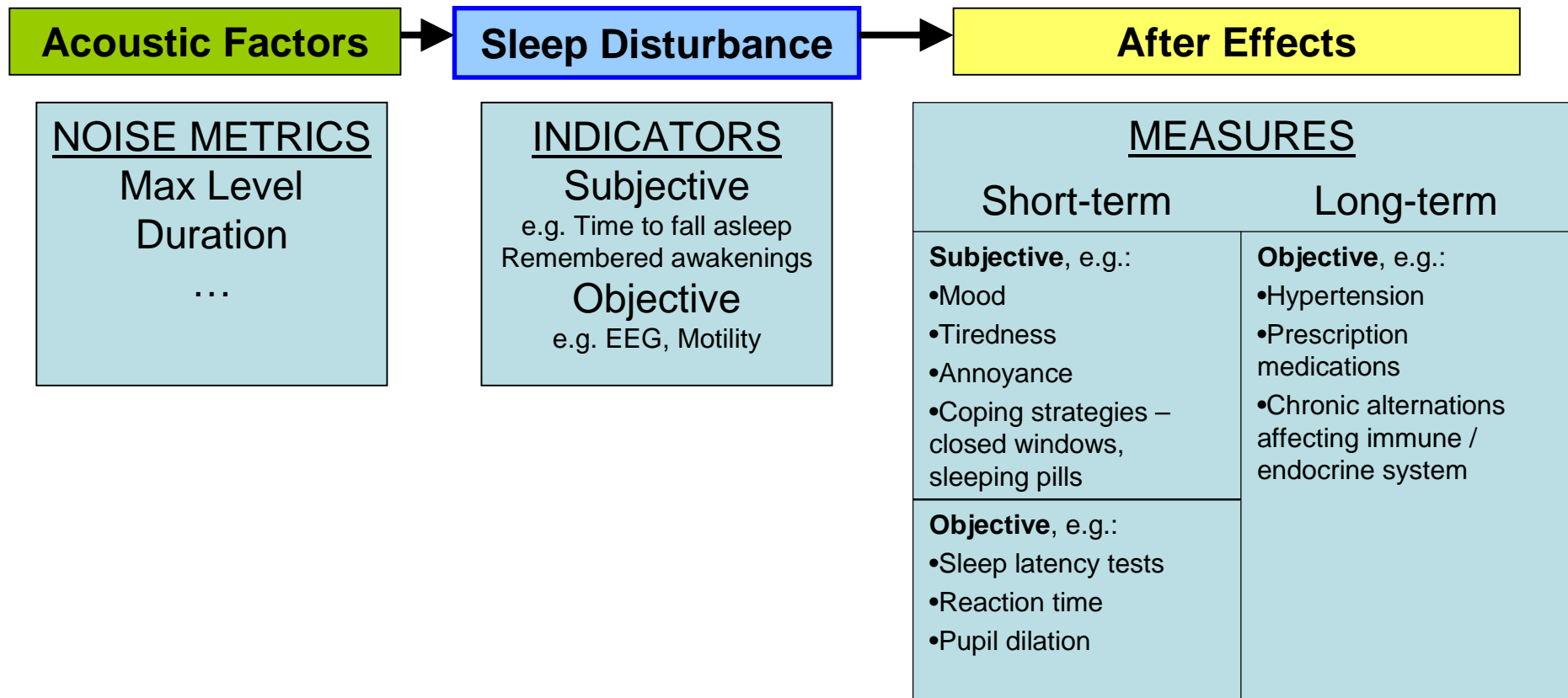
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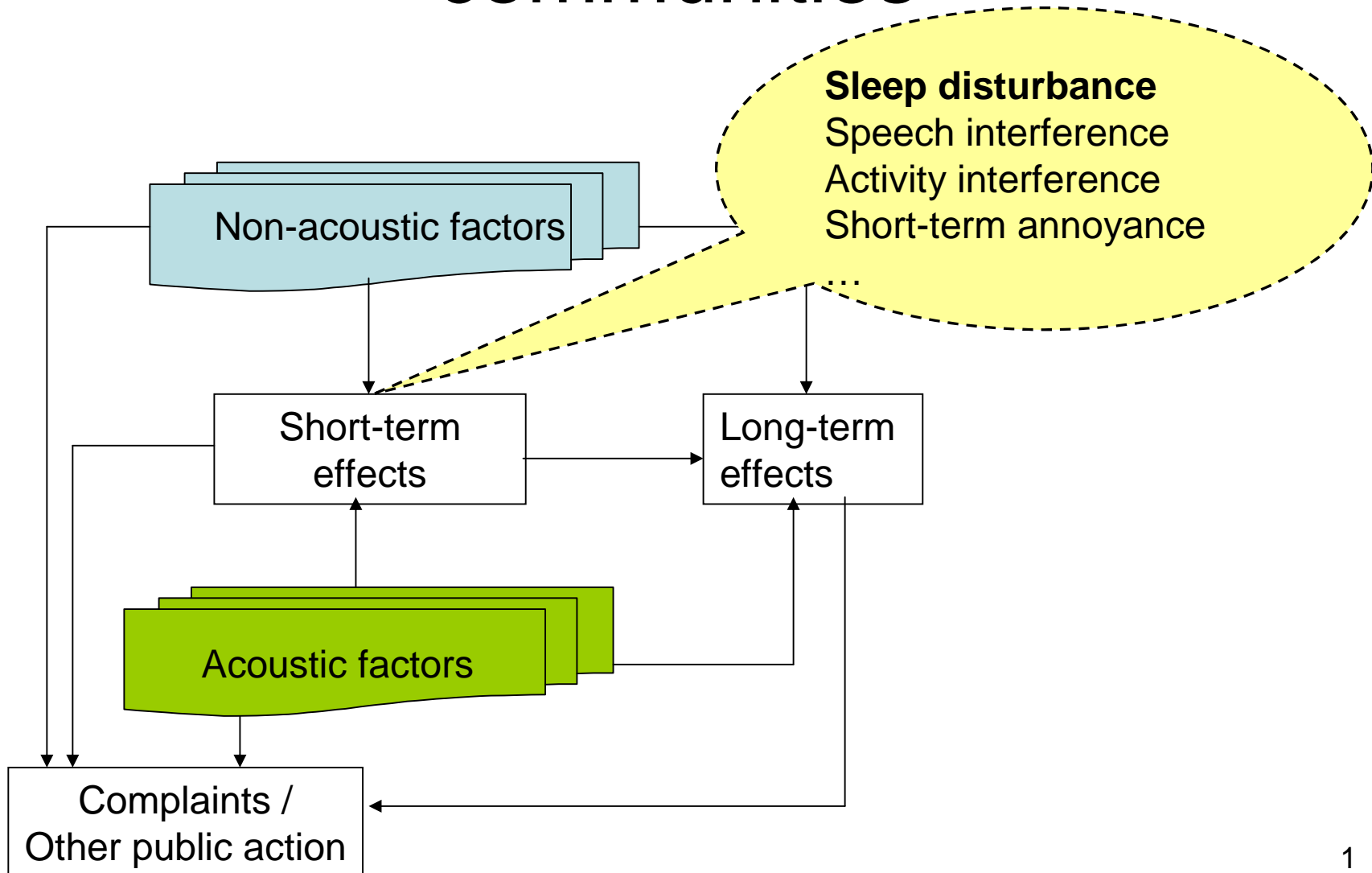
Sleep disturbance

- Construct initial model of noise related causes of sleep disturbance and associated effects
- Identify questions FAA needs to answer
- Relate questions to model
- Identify parts of model where improved understanding will help answer questions
- Construct research roadmap that will improve understanding

Initial model for aircraft noise-induced sleep disturbance

- Culture
- Age
- Health
- Location of residence
- Duration of residence
- Tiredness
- Time of retiring
- Sleep stage
- Noise sensitivity
- Vulnerable populations

…

- Max sound level
- No. events
- Time of event
- Vibration/rattle
- Event time history
- Frequency spectrum
- Tonality
- Ambient sound levels

…

Non-acoustic factors

Acoustic factors

Sleep disturbance

After Effects

Short Term Effects

Long Term Effects

Terminology

For primary parts of model we will investigate.

Acoustic Factors	→	Sleep Disturbance	→	After Effects

NOISE METRICS
Max Level
Duration
…

INDICATORS
Subjective
e.g. Time to fall asleep
Remembered awakenings
Objective
e.g. EEG, Motility

MEASURES

Short-term	Long-term
Subjective, e.g.: •Mood •Tiredness •Annoyance •Coping strategies – closed windows, sleeping pills **Objective**, e.g.: •Sleep latency tests •Reaction time •Pupil dilation	**Objective**, e.g.: •Hypertension •Prescription medications •Chronic alternations affecting immune / endocrine system

Fundamental questions that need answers

1. What effects of sleep disturbance should / can FAA seek to limit?

Short Term Effects   **Long Term Effects**

2. To what extent should the effects be limited?

Need ways to measure the effects

3. How can FAA limit the effects?

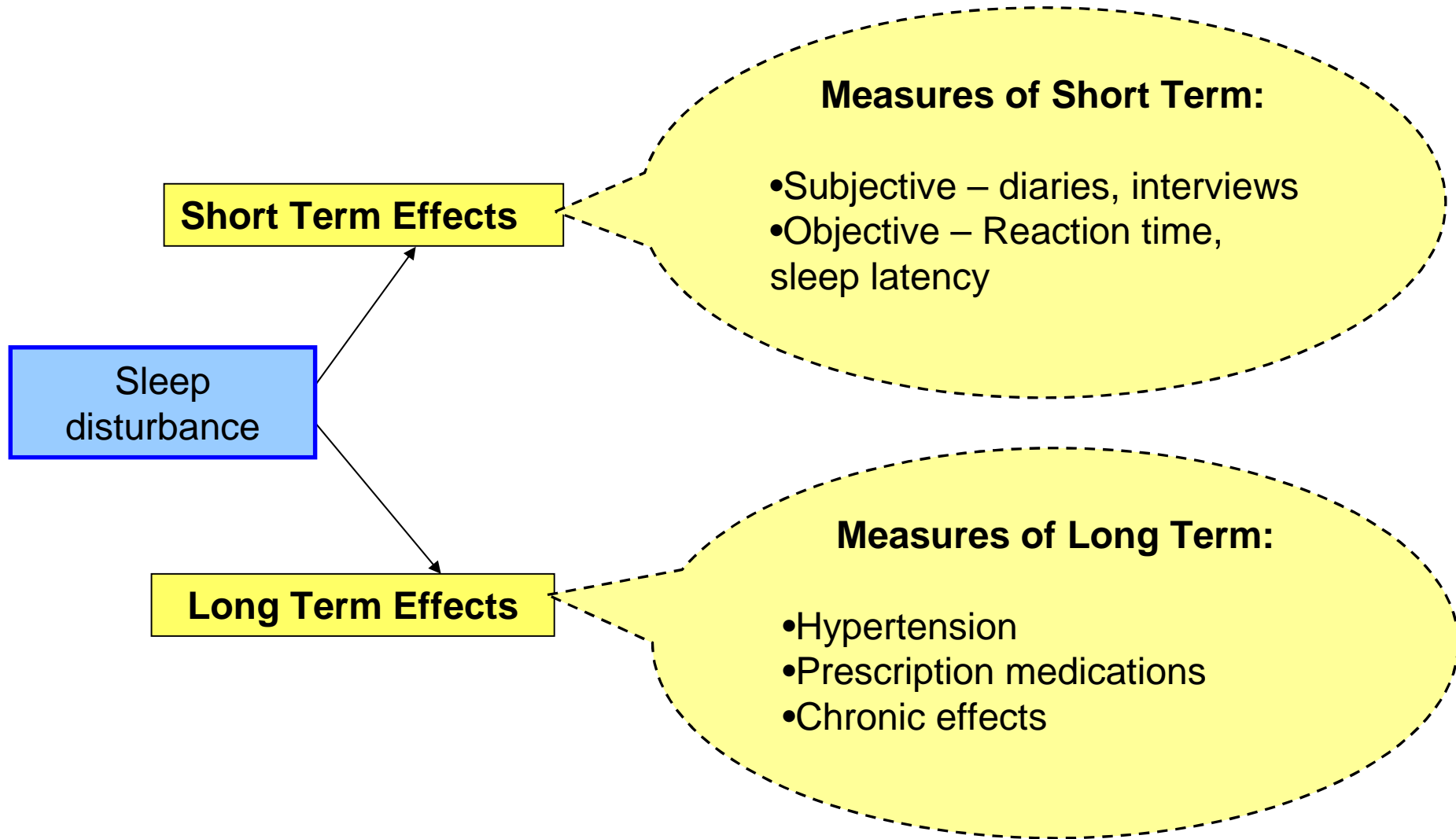**Identify factors FAA might control that affect sleep disturbance**

4. What data are available to provide answers?

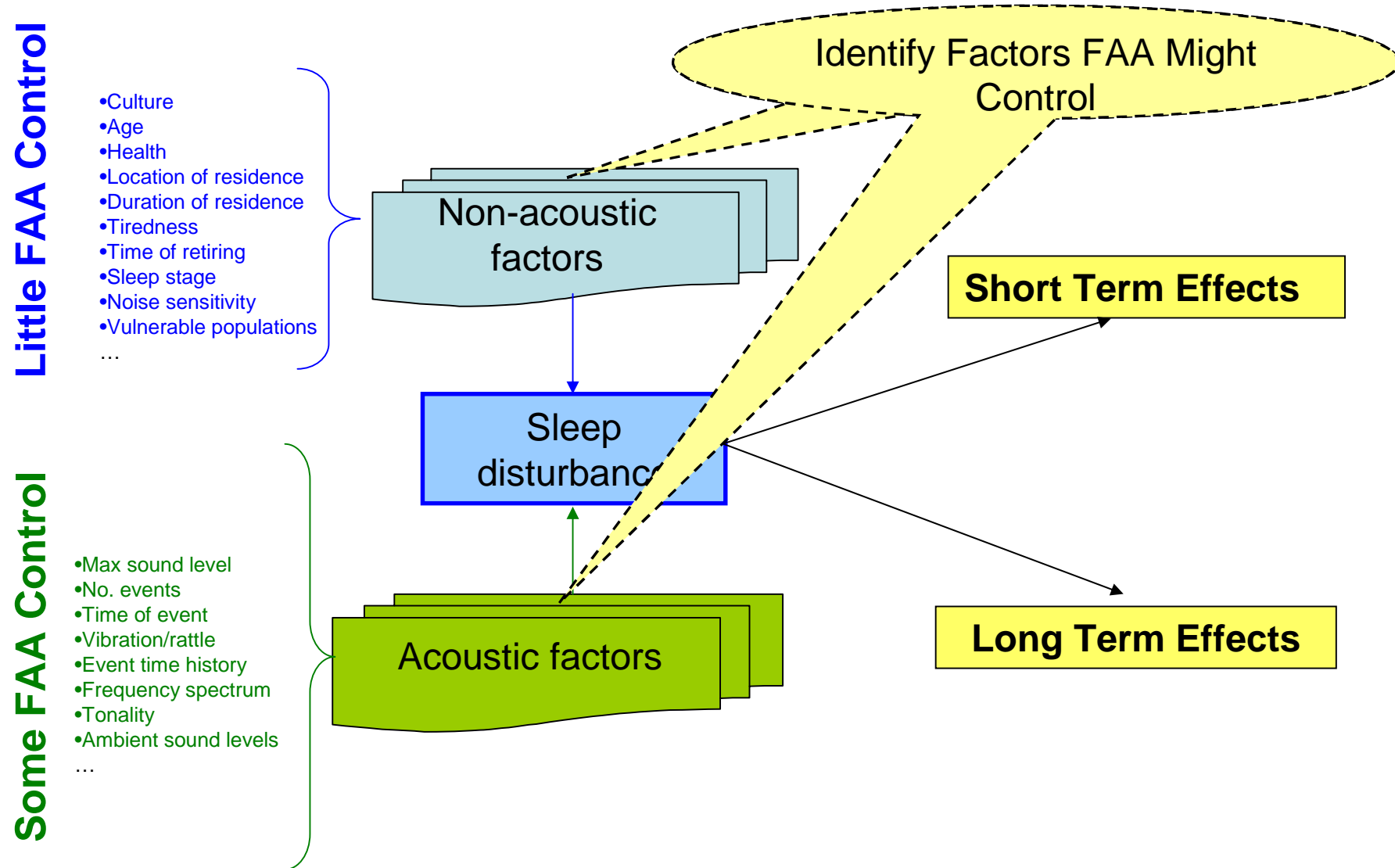5. What additional studies are needed?

Proposed development of roadmap to answering these questions

- Examine each question's relation to model
- Develop initial series of "actionable hypotheses" to step-wise improve understanding of the model and ability to answer the fundamental questions.
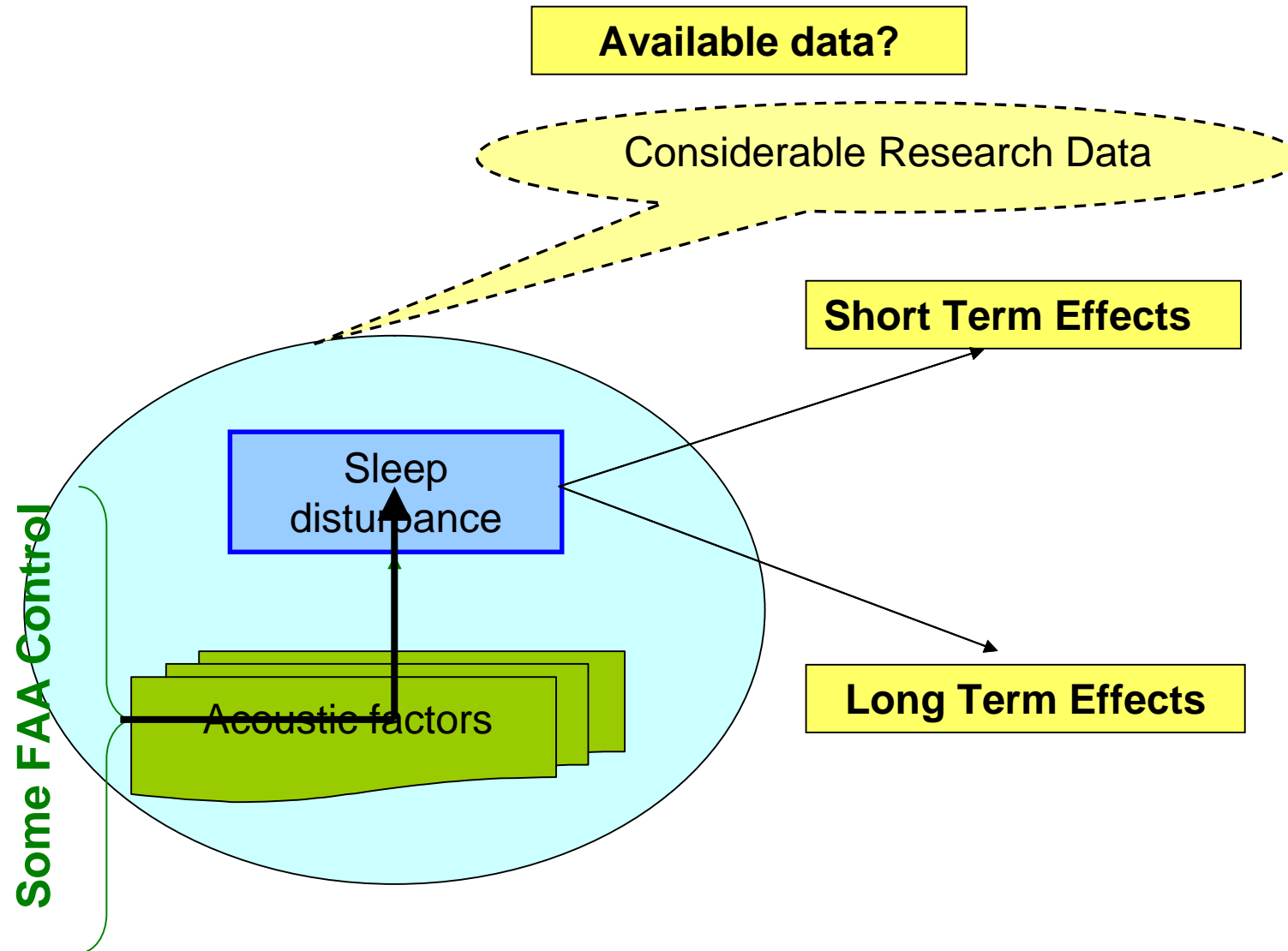- Design research tasks to test hypotheses

1. What effects should / can FAA seek to limit?
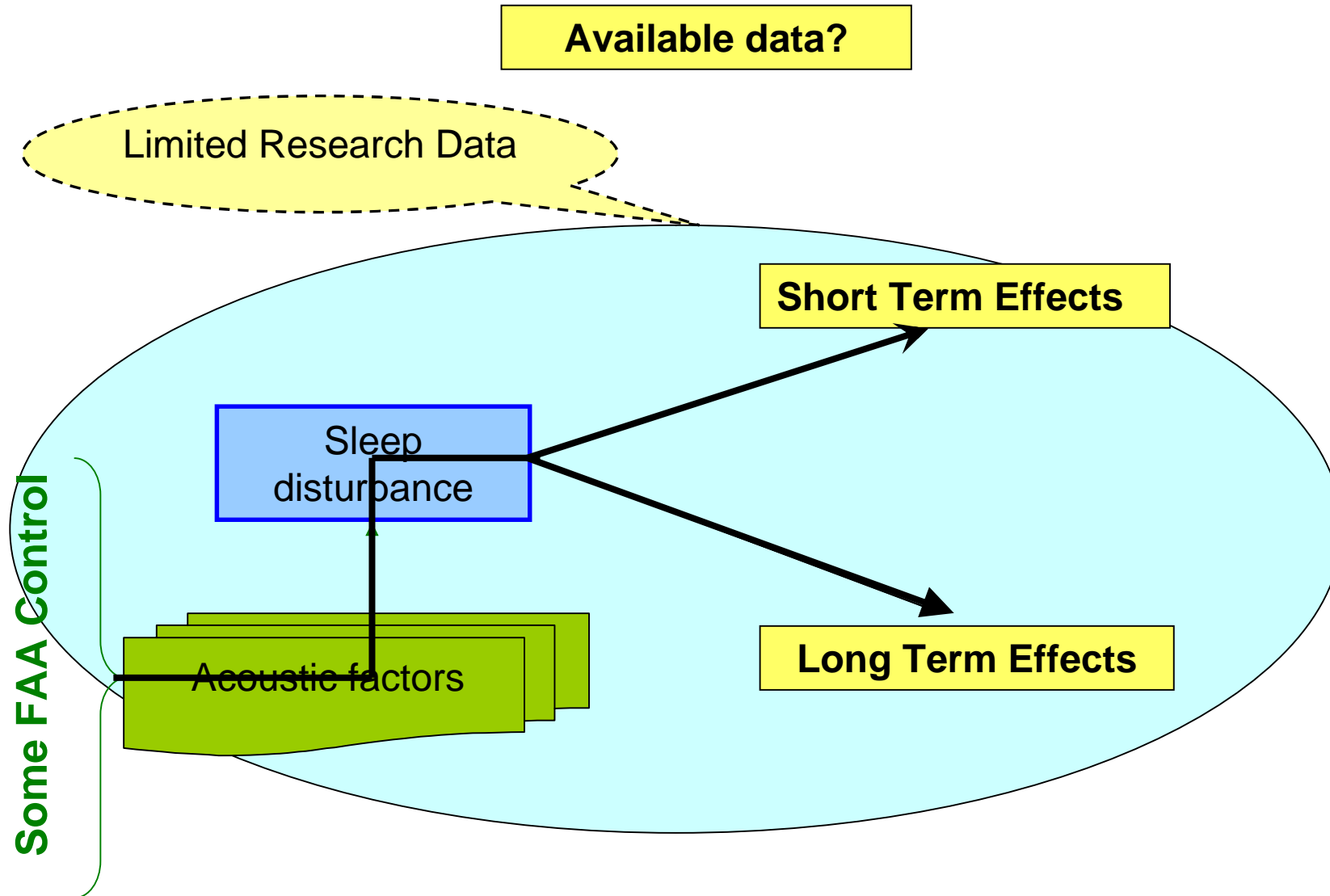# 2. To what extent should the effects be limited?

Short Term Effects

Sleep disturbance

Long Term Effects

Measures of Short Term:

- Subjective – diaries, interviews
- Objective – Reaction time, sleep latency

Measures of Long Term:

- Hypertension
- Prescription medications
- Chronic effects

3. How can FAA limit the effects?

Little FAA Control

- Culture
- Age
- Health
- Location of residence
- Duration of residence
- Tiredness
- Time of retiring
- Sleep stage
- Noise sensitivity
- Vulnerable populations
...

Non-acoustic factors

Some FAA Control

- Max sound level
- No. events
- Time of event
- Vibration/rattle
- Event time history
- Frequency spectrum
- Tonality
- Ambient sound levels
...

Acoustic factors

Sleep disturbance

Identify Factors FAA Might Control

Short Term Effects

Long Term Effects

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3. How can FAA limit the effects?

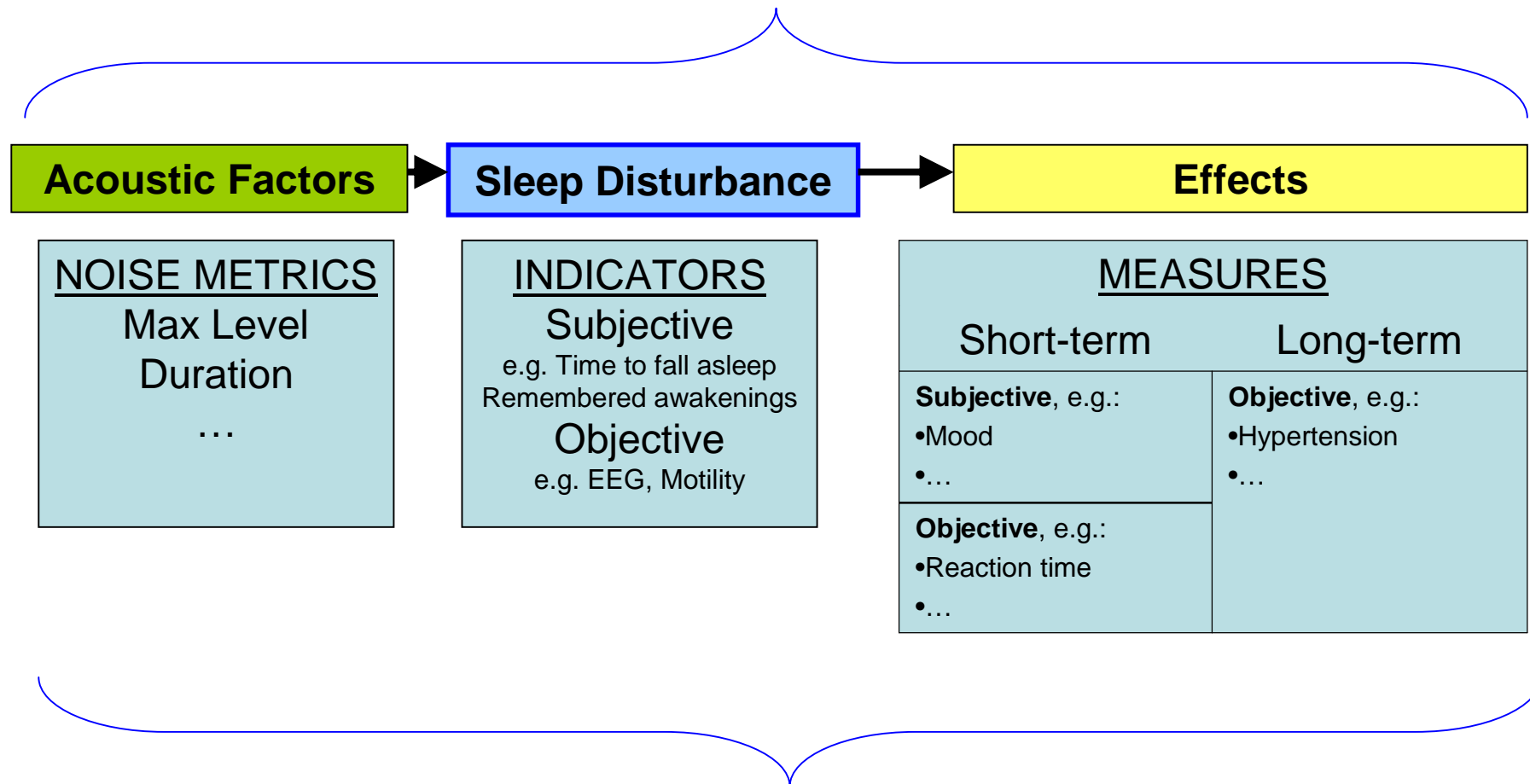# 3. How can FAA limit the effects?

Actionable Hypothesis # S1

- At this stage of investigation, we need to assemble everything available that is known internationally about noise and sleep disturbance. Considerable research studies and results have been published and improvements in understanding must begin with what is already known.

- *Data and results from available studies of noise induced sleep disturbance can be organized and summarized in a way that permits cross-comparisons of all **noise metrics**, **indicators** of sleep disturbance and **measures** of effects*

Summary of Sleep Hypotheses

S1. Assemble Available Studies / Data

Acoustic Factors	Sleep Disturbance	Effects

NOISE METRICS
Max Level
Duration
…

INDICATORS
Subjective
e.g. Time to fall asleep
Remembered awakenings
Objective
e.g. EEG, Motility

MEASURES

Short-term	Long-term
Subjective, e.g.: •Mood •…	**Objective**, e.g.: •Hypertension •…
Objective, e.g.: •Reaction time •…	

Developing the Research Roadmap

Applicability of available data to U.S. populations?
Do non-acoustic factors differentiate populations significantly?

Considerable Research Data But…

Limited U.S. Data

Considerable Data on Other Populations
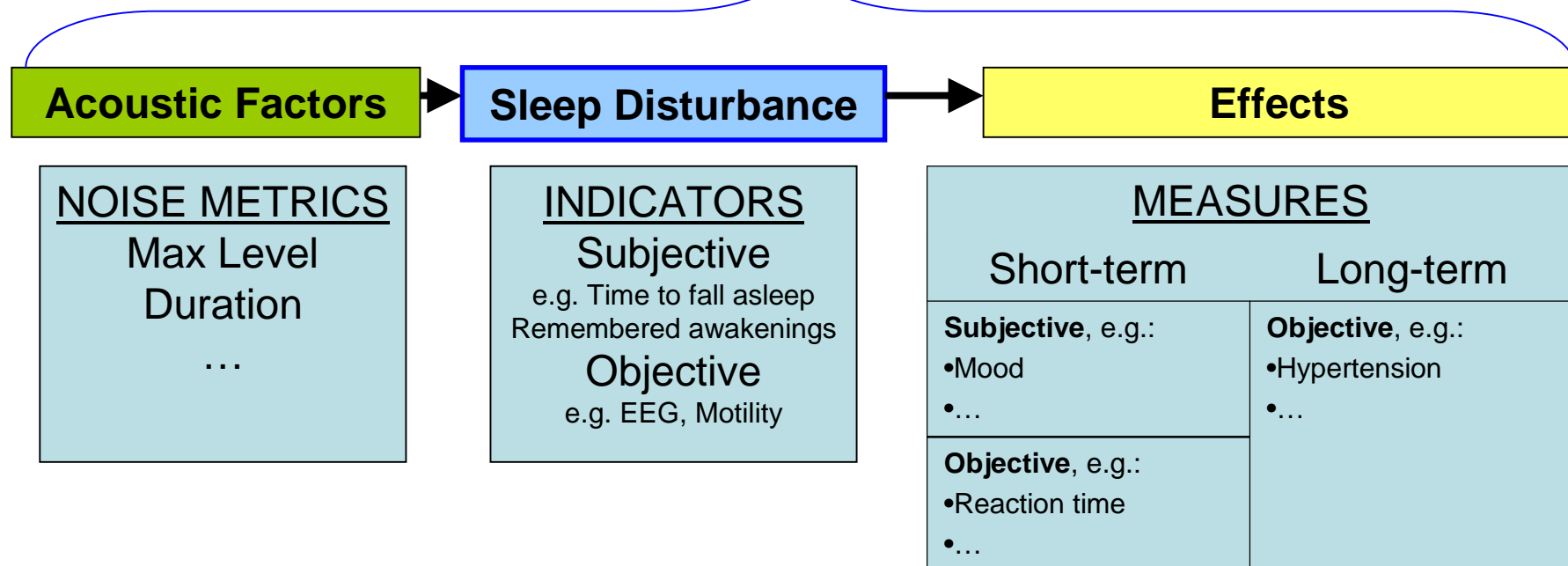
Some FAA Control

Sleep disturbance

Acoustic factors
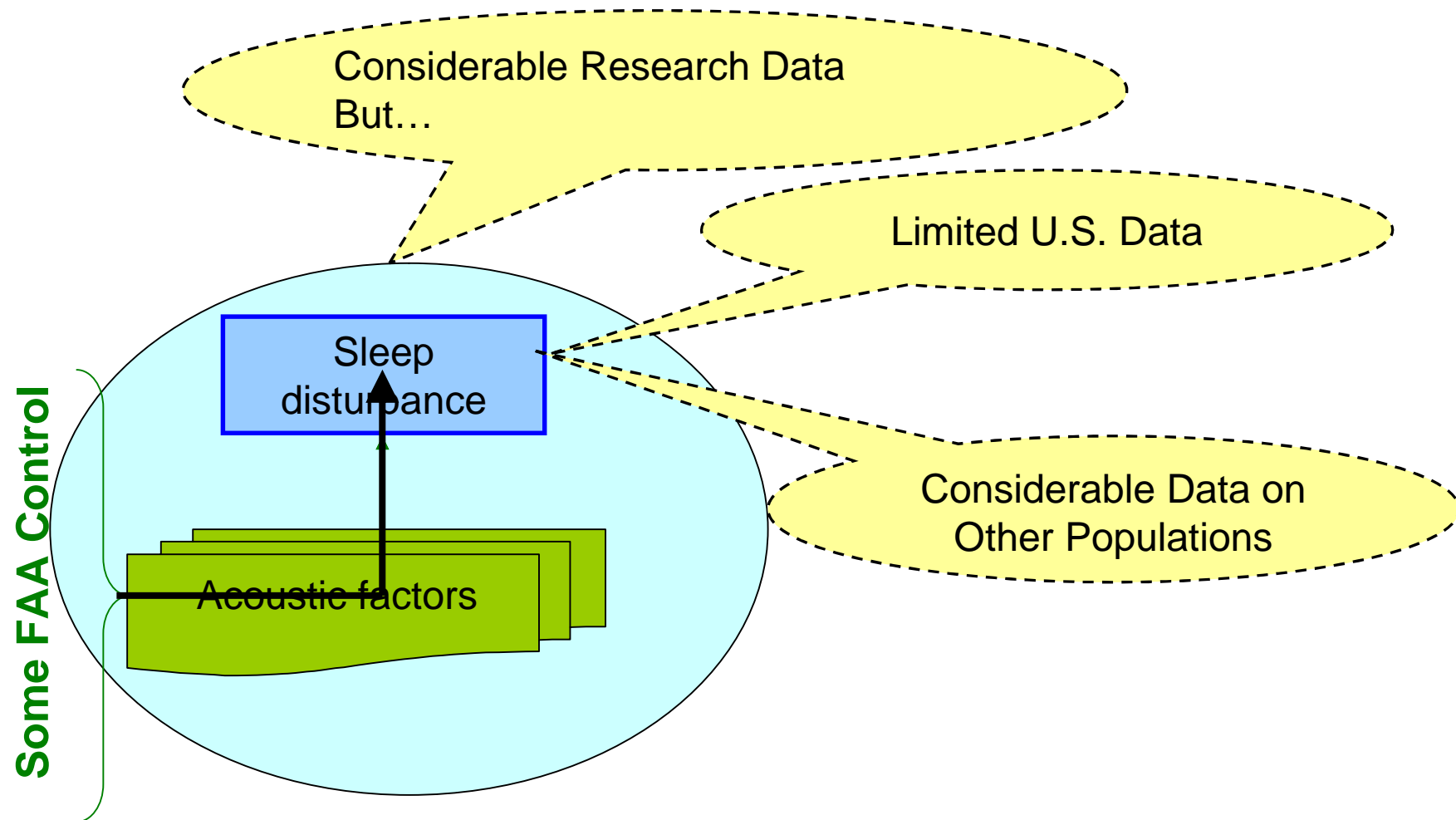
Actionable Hypothesis # S2

- Relatively few noise and sleep disturbance studies have been conducted around airports in the U.S. Examine data to understand whether all populations are similar in their sleep disturbance responses, and that consequently all study findings are reasonably applicable to U.S. populations.

- *Populations are similar in their responses to aircraft noise*
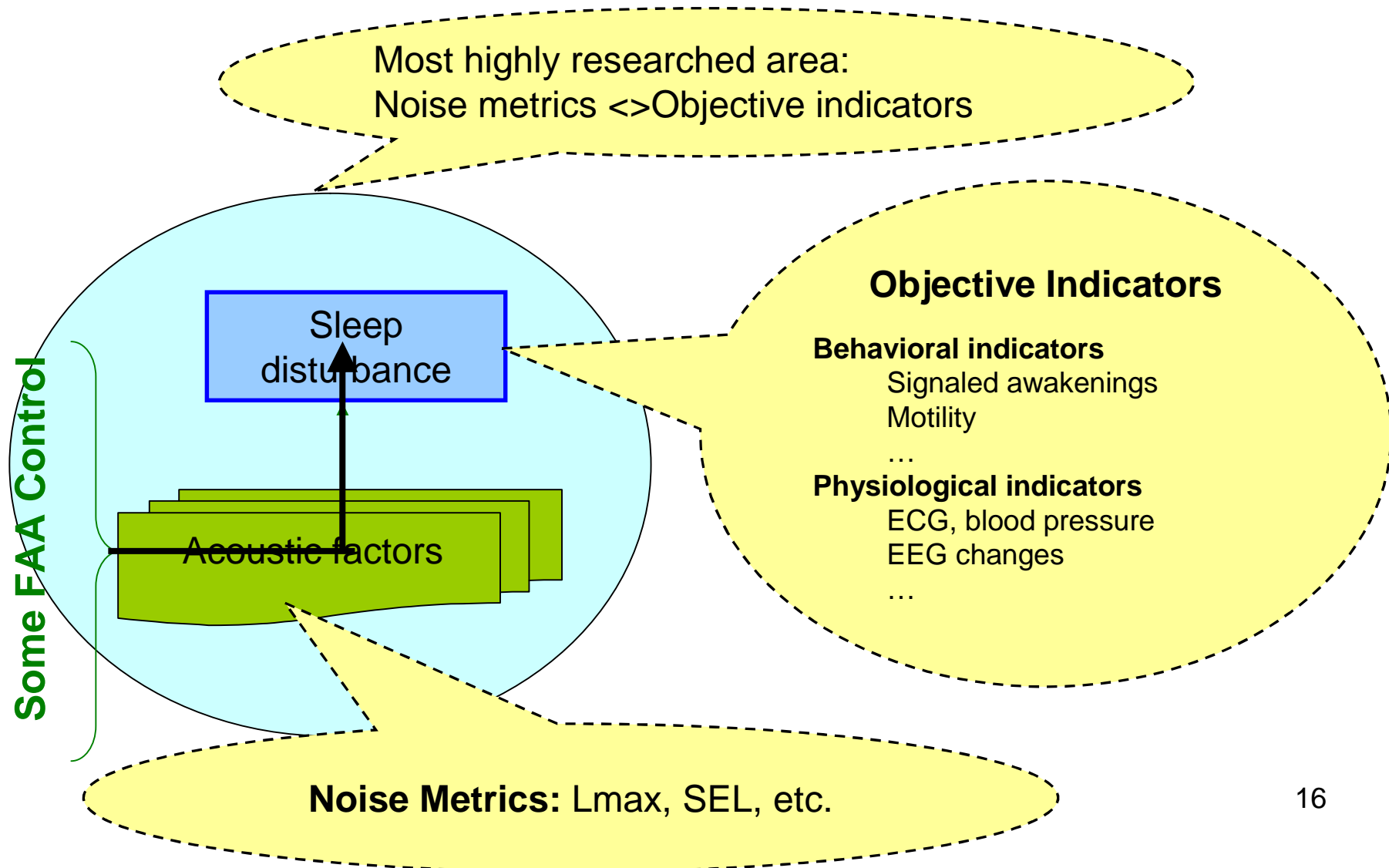
Summary of Sleep Hypotheses

S1. Assemble Available Studies / Data

S2. Examine Consistency Across Populations

Acoustic Factors	Sleep Disturbance	Effects

NOISE METRICS
Max Level
Duration
…

INDICATORS
Subjective
e.g. Time to fall asleep
Remembered awakenings
Objective
e.g. EEG, Motility

MEASURES

Short-term	Long-term
Subjective, e.g.: •Mood •…	**Objective**, e.g.: •Hypertension •…
Objective, e.g.: •Reaction time •…	

Developing the Research Roadmap

Correlation of noise metrics with objective indicators of sleep disturbance

Most highly researched area:
Noise metrics <>Objective indicators

Some FAA Control

Sleep disturbance

Acoustic factors

Objective Indicators

Behavioral indicators
Signaled awakenings
Motility
…
Physiological indicators
ECG, blood pressure
EEG changes
…

Noise Metrics: Lmax, SEL, etc.

Actionable Hypothesis # S3

- This hypothesis permits a review and summary of the considerable number of available studies and results relating noise metrics and the objective indicators.

- *Noise metrics are similarly related to the various objective indicators of sleep disturbance*
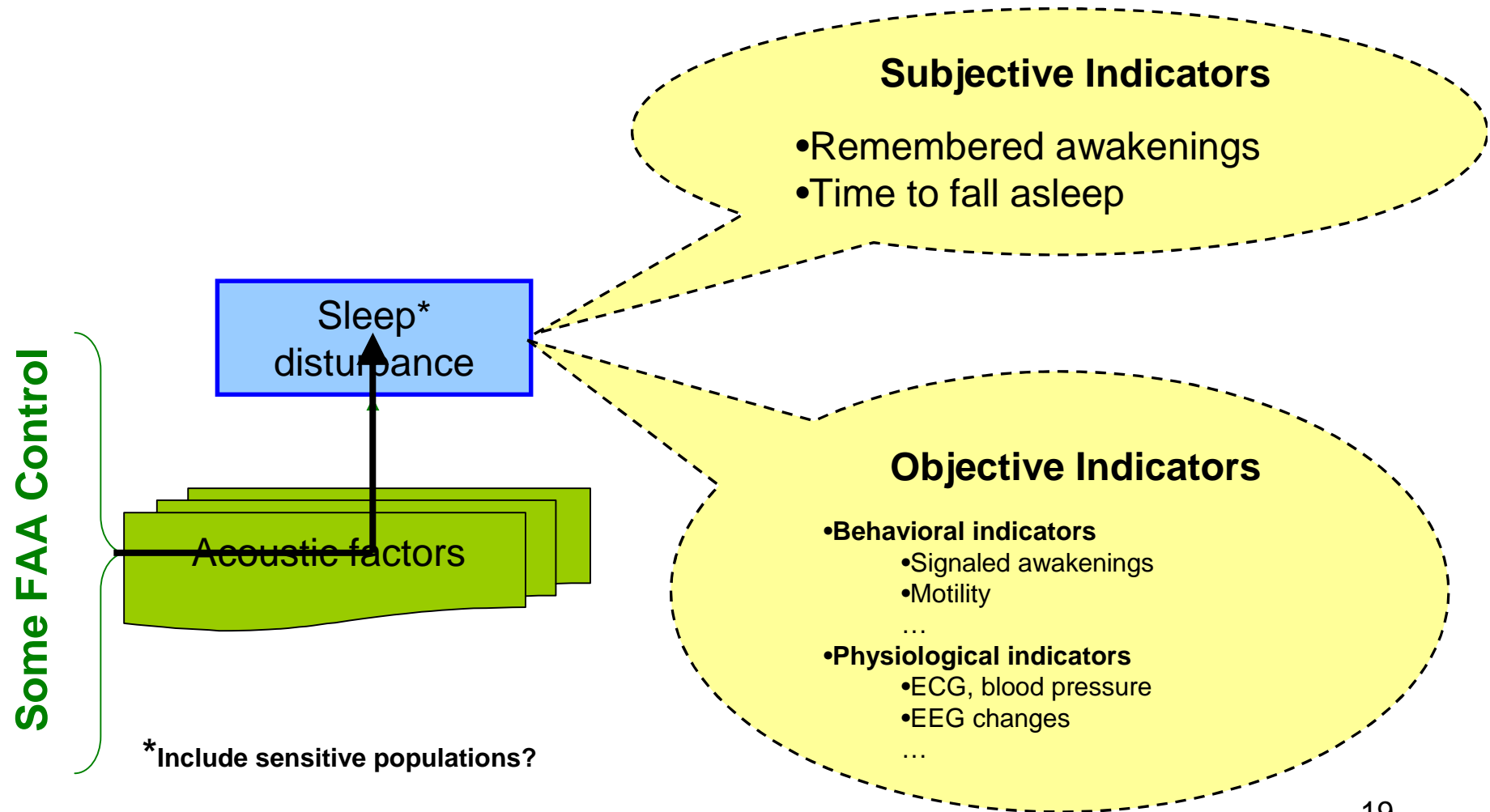
Summary of Sleep Hypotheses

S1. Assemble Available Studies / Data

S2. Examine Consistency Across Populations

Acoustic Factors	Sleep Disturbance	Effects

NOISE METRICS	INDICATORS	MEASURES
Max Level Duration …	Subjective e.g. Time to fall asleep Remembered awakenings Objective e.g. EEG, Motility	Short-term / Long-term

S3.

MEASURES

Short-term

Subjective, e.g.:
- Mood
- …

Objective, e.g.:
- Reaction time
- …

Long-term

Objective, e.g.:
- Hypertension
- …
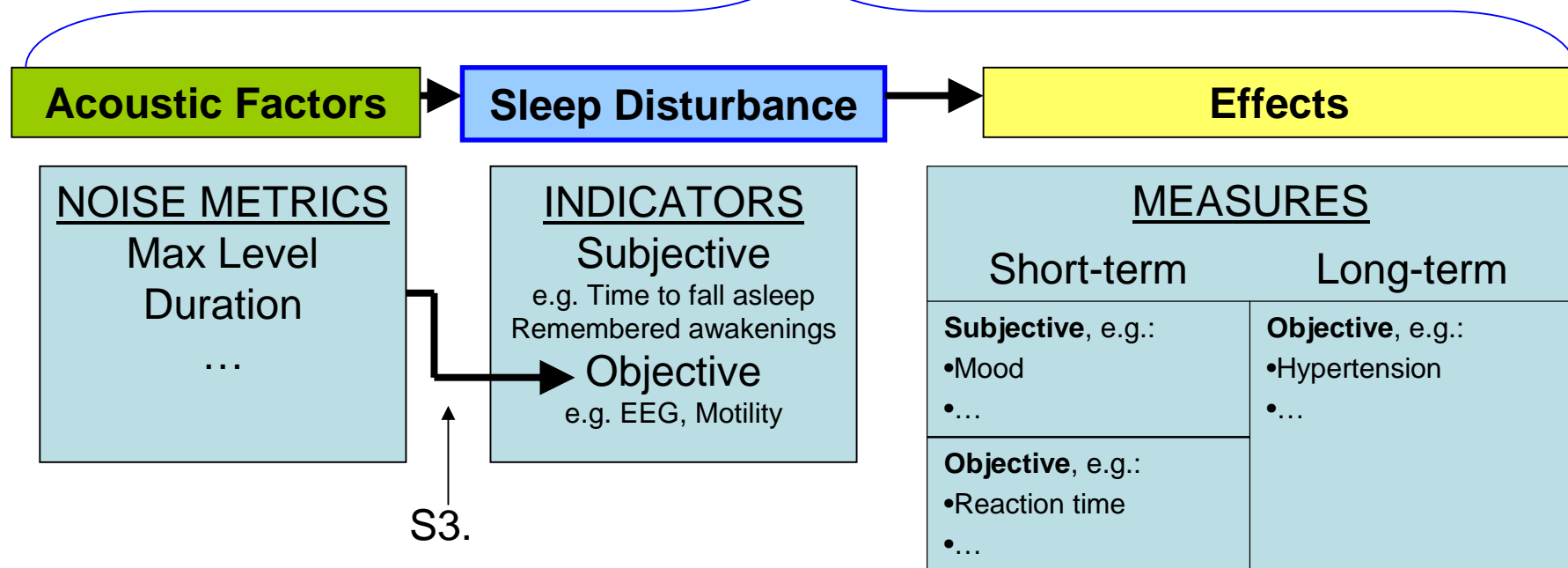
Developing the Research Roadmap

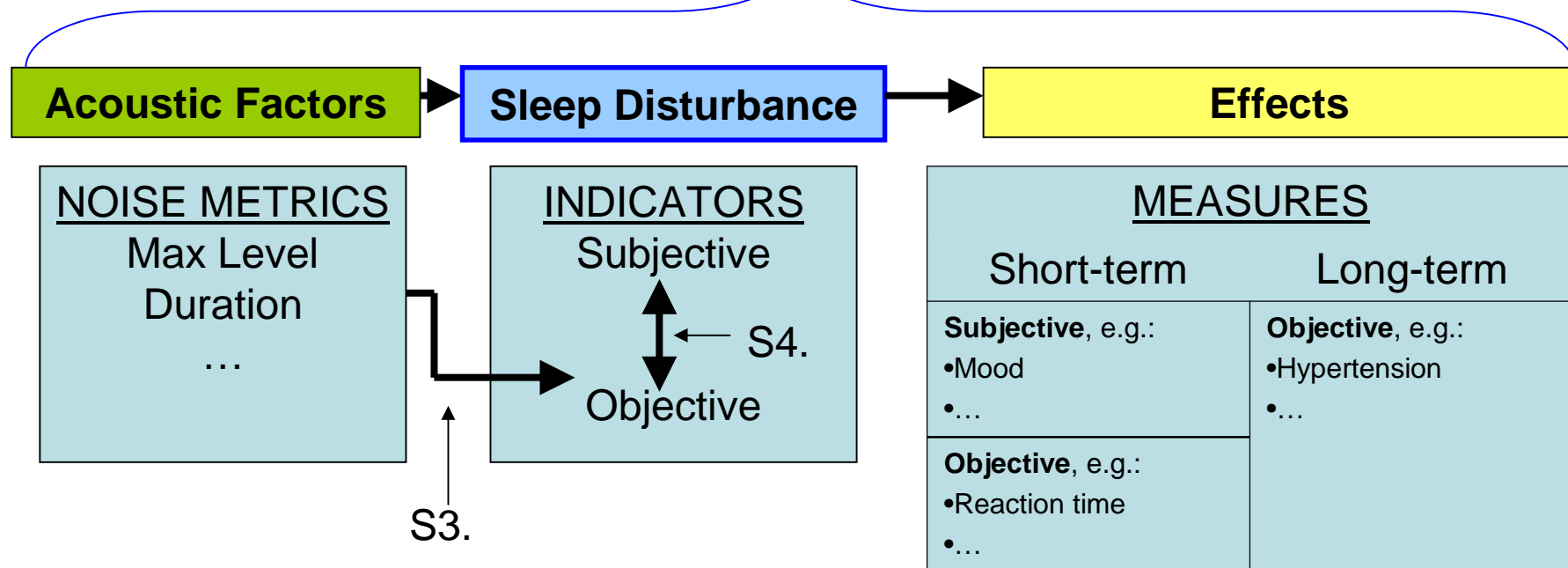**Are objective (the more researched) indicators of sleep disturbance correlated with subjective indicators?**

Subjective Indicators

- Remembered awakenings
- Time to fall asleep

Sleep* disturbance

Some FAA Control

Acoustic factors

*Include sensitive populations?

Objective Indicators

- **Behavioral indicators**
  - Signaled awakenings
  - Motility
  - …
- **Physiological indicators**
  - ECG, blood pressure
  - EEG changes
  - …

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Actionable Hypothesis # S4

Such correlation, or lack thereof, will assist in determining, for example, whether FAA efforts directed at the limiting the objective indicators of sleep disturbance are likely to **affect how people judge the quality of their sleep**. High correlation could also mean that collection of sleep disturbance information may be as simple as **asking people about their subjective evaluation** of their sleep.

- *Subjective and objective indicators of sleep disturbance are correlated for nights of sleep disturbed by noise events.*

Summary of Sleep Hypotheses

S1. Assemble Available Studies / Data

S2. Examine Consistency Across Populations

Acoustic Factors	Sleep Disturbance	Effects

NOISE METRICS
Max Level
Duration
…

INDICATORS
Subjective
↕ ← S4.
Objective

S3.

MEASURES

Short-term	Long-term
Subjective, e.g.: •Mood •…	**Objective**, e.g.: •Hypertension •…
Objective, e.g.: •Reaction time •…	

Developing the Research Roadmap

Are objective indicators of sleep disturbance correlated with measures of short-term effects?

Short Term Effects

Sleep disturbance

Long Term Effects

Short Term Effects
- **Subjective reports**
  - Tiredness
  - …
- **Objective measures** –
  - Pupil dilation
  - Reaction times
  - …

Objective Indicators

- **Behavioral indicators**
  - Signaled awakenings
  - Motility
  - …
- **Physiological indicators**
  - ECG, blood pressure
  - EEG changes
  - …
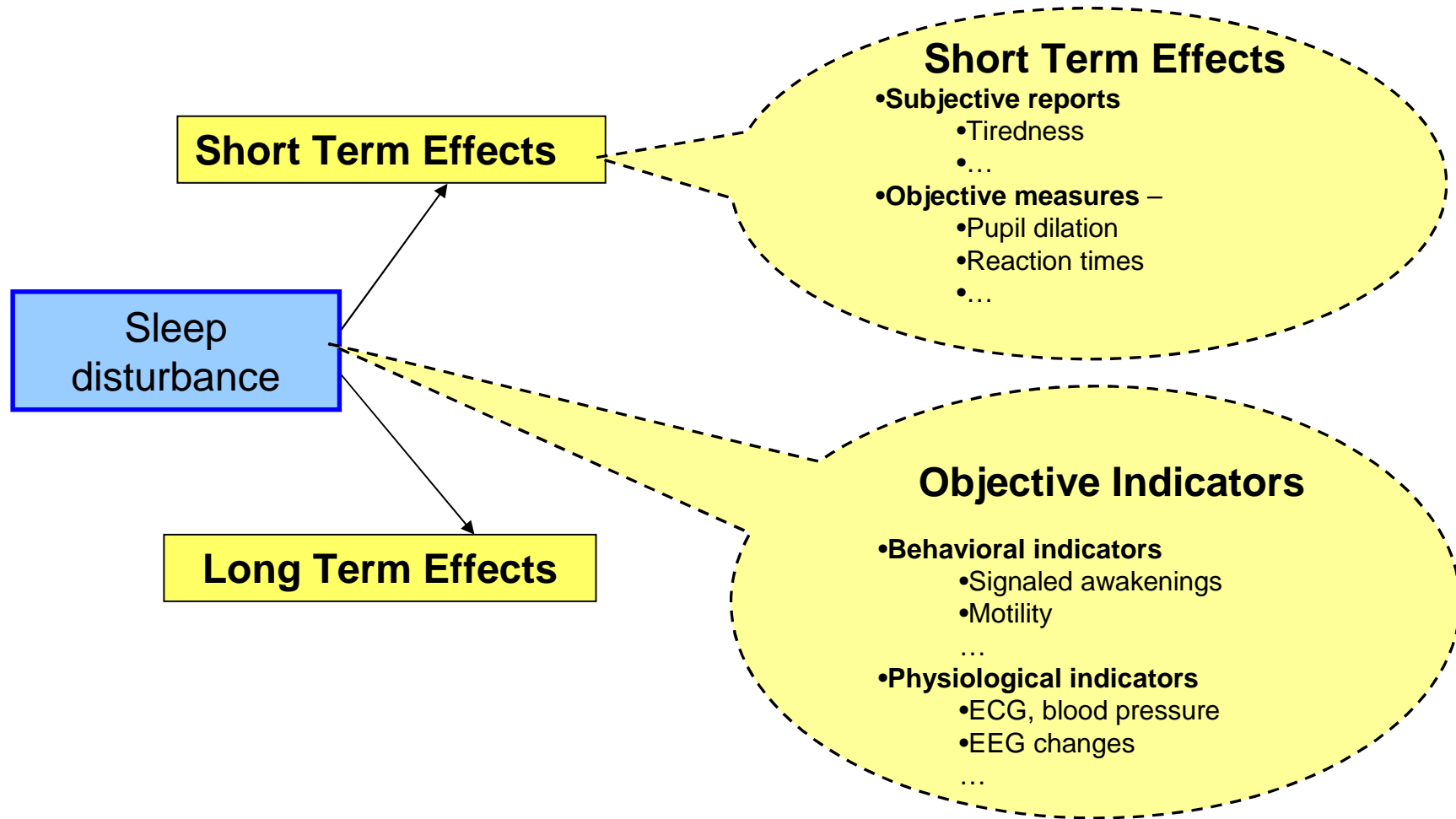
Actionable Hypothesis # S5

Long-term health effects resulting from noise induced sleep disturbance are too uncertain at this time to benefit from a limited study. Short-term effects may be more tractable. This hypothesis provides for examination of the relationships across objective indicators and all studied measures of short-term effects.

- *Noise induced sleep disturbance as determined by objective indicators result in adverse short-term performance / health effects*

Summary of Sleep Hypotheses

S1. Assemble Available Studies / Data

S2. Examine Consistency Across Populations

Acoustic Factors → **Sleep Disturbance** → **Effects**

NOISE METRICS
Max Level
Duration
…

INDICATORS
Subjective
← S4.
Objective

S3.

MEASURES

Short-term   Long-term

Subjective, e.g.:
•Mood
•…

Objective, e.g.:
•Hypertension
•…

Objective, e.g.:
•Reaction time
•…

S5.
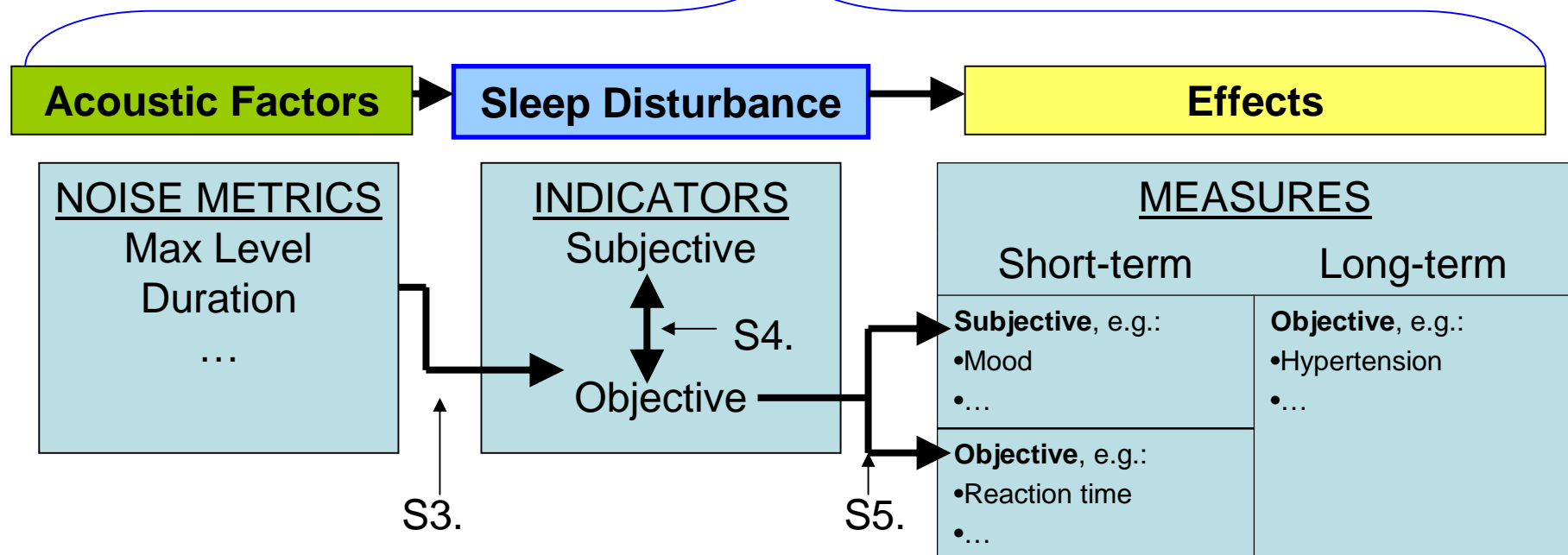
Actionable Hypothesis # S6

- Sleep disturbance occurs **whether or not noise events are present**. This hypothesis intends to explore the differences between this "normal" sleep disturbance, and noise induced sleep disturbance.

- *There are significant sleep disturbance differences between aircraft noise exposed and non-aircraft noise exposed populations*

Summary of Sleep Hypotheses

S1. Assemble Available Studies / Data

S2. Examine Consistency Across Populations.
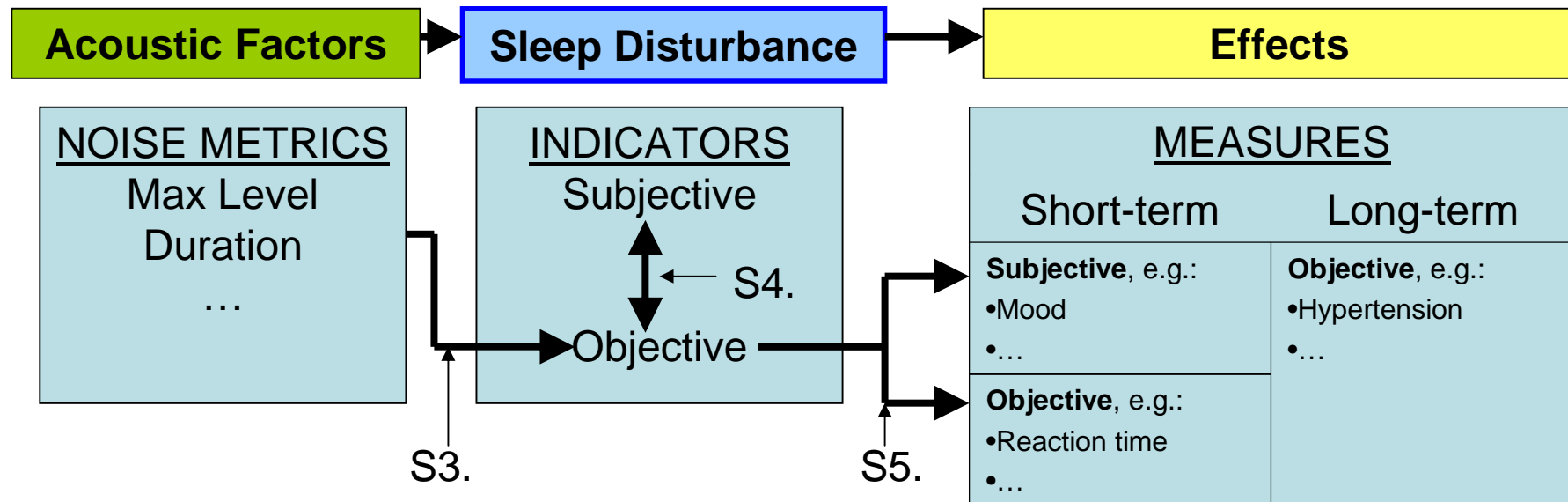
S6. Compare noise exposed / non-noise exposed populations.

Actionable Hypothesis # S7

- There exists a considerable body of sleep research – its benefits and the adverse effects of sleep disturbance. FAA wishes any noise related sleep research to benefit from work in this related field.

- *The effects of **non-noise sleep disturbance studies** can help identify which indicators of sleep disturbance are best correlated with the health and performance effects that may result*

Summary of Sleep Hypotheses

S1. Assemble Available Studies / Data

S2. Examine Consistency Across Populations
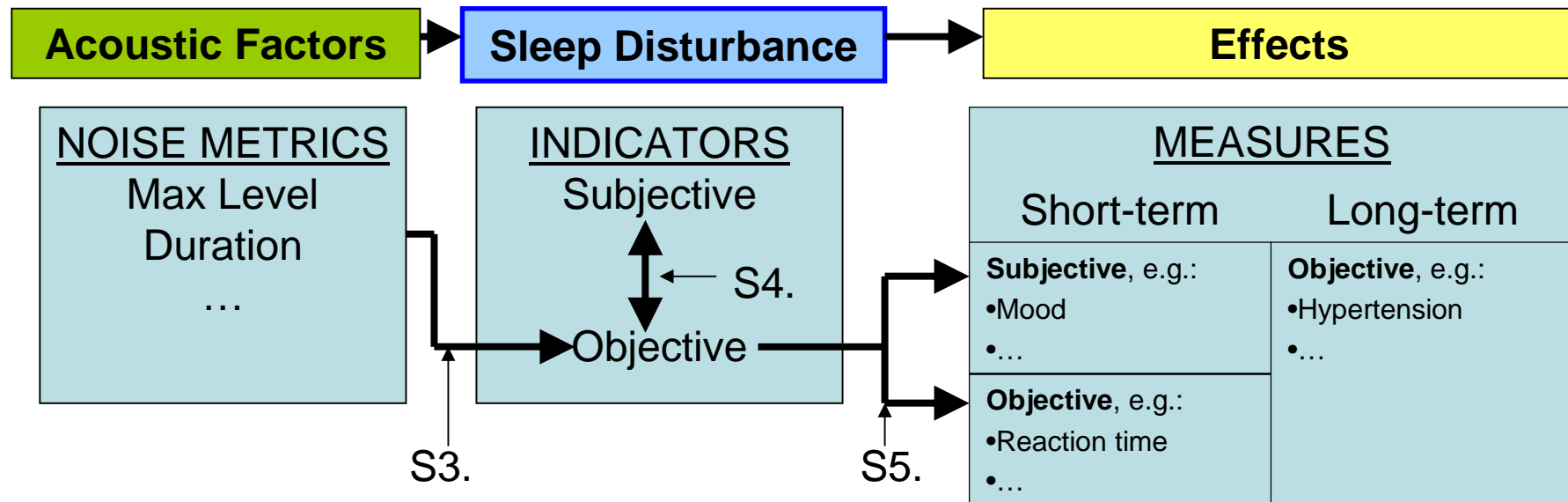
S6. Compare noise exposed / non-noise exposed populations.

S7. Use non-noise sleep disturbance study findings

Actionable Hypothesis # S8

- The World Health Organization has proposed night noise guidelines for Europe using $L_{night,outside}$ to protect populations from awakening. Noise induced awakenings result from single noise events. As part of the research, FAA wishes to examine the relationships among various methods and noise metrics for protecting populations.

- *The value of $L_{night,outside}$ is a reliable predictor of noise-induced awakenings and both correlate with a suitably derived model for computing awakenings*

Some Approaches to Limiting Nighttime Aircraft Noise

- Metrics:
  - European Union: Lnight
  - WHO Recommendations
  - Limit nighttime indoor LAmax Levels (e.g. Frankfurt airport 52 dBA)

- Other
  - Nighttime protection zone - Leipzig-Halle Airport
  - Fines (e.g. Edinburgh, Manchester, etc.)

- Operations:
  - Night-time Curfews (e.g. Naples International, Zurich, etc.)
  - Restrictions imposed on number and\or type of operations during the night and \or during "shoulder" hours (e.g. Sydney, Zurich, Minneapolis St. Paul International, etc.)
  - Preferential nighttime runways (e.g. Calgary International, Athens International, Amsterdam-Schiphol, etc.)
  - Noise abatement flight paths (e.g. O'Hare International, Tucson International, Los Angeles International, Seattle-Tacoma International, etc.)
  - Noise abatement flight procedures-e.g. restrict use of reverse thrust, etc. (e.g. Sydney, Athens International, etc.)

Summary of Sleep Hypotheses

S1. Assemble Available Studies / Data

S2. Examine Consistency Across Populations
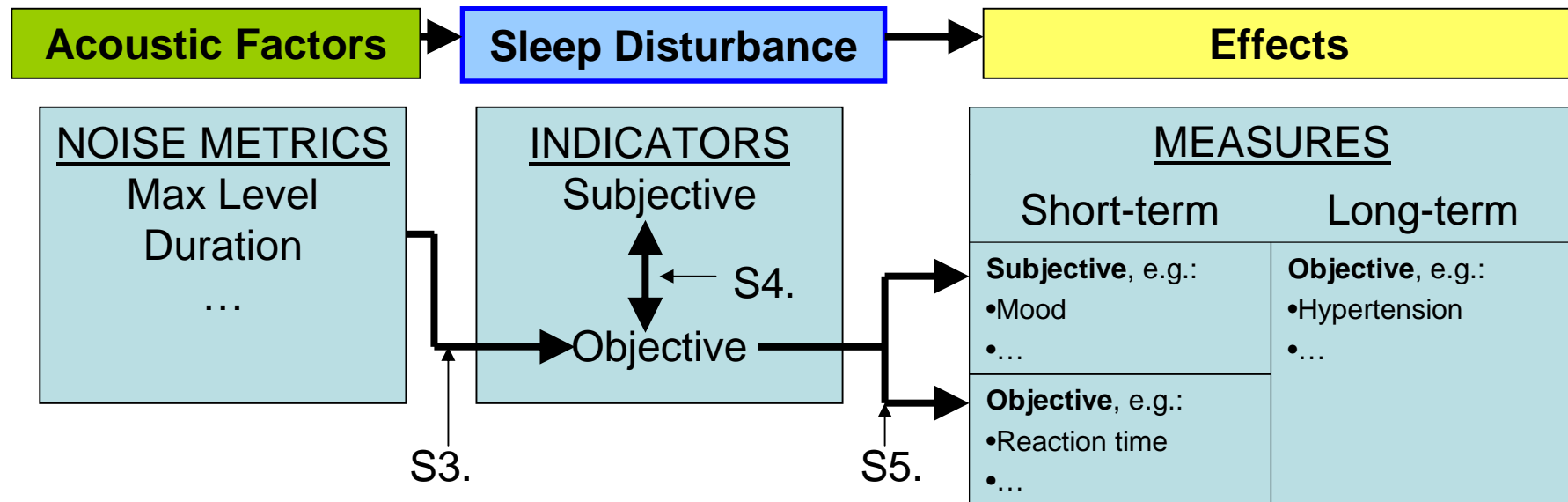
S6. Compare noise exposed / non-noise exposed populations.

S7. Use non-noise sleep disturbance study findings

S8. Compare $L_{night,outside}$ to incidents of sleep disturbance

End